The New Atom Smashers

Wreckage from the ultimate high-speed collision will reveal nature's most closely held secrets.

BY JIM WILSON

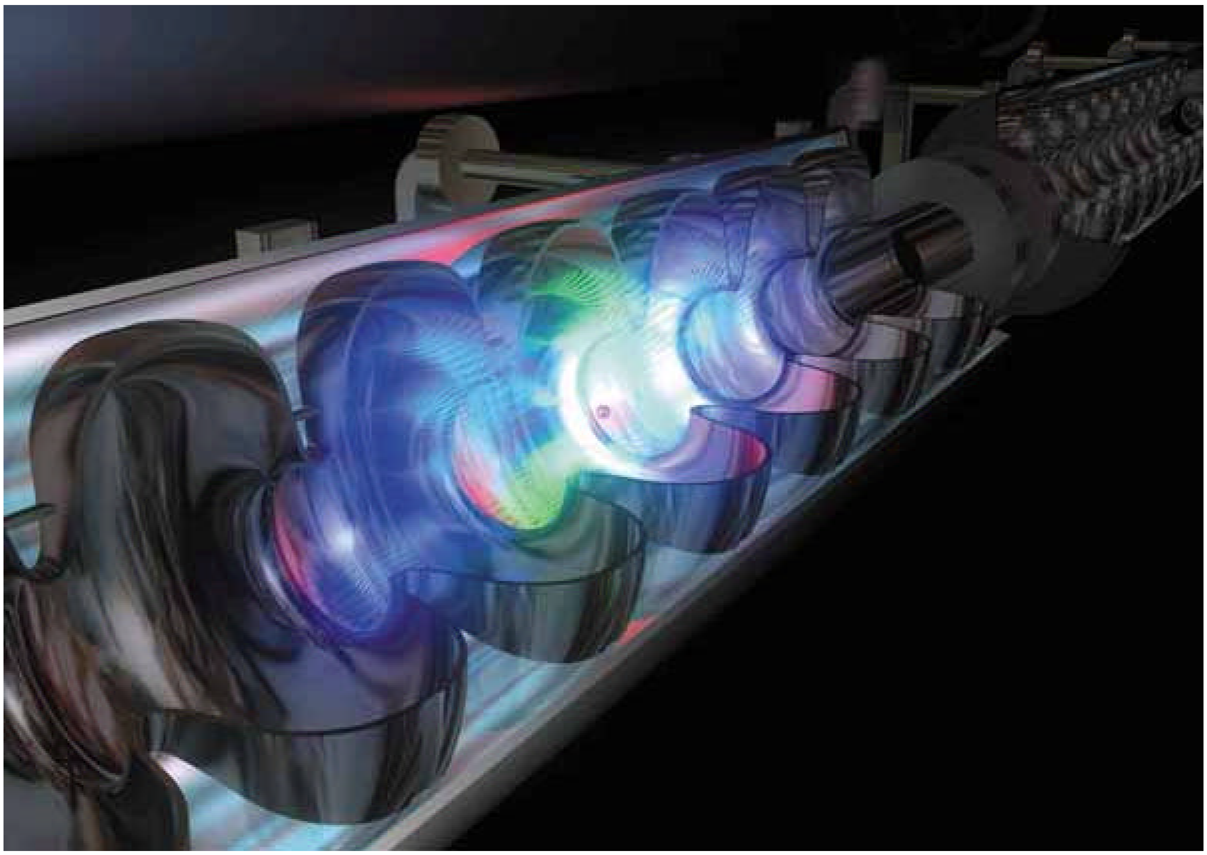

Illustration by German Electron Synchrotron DESY, Hamburg, Germany

In bustling conference rooms in the United States, Europe and Japan, the world's top physicists are hard at work designing a machine that will answer the most profound question in modern science: Why is it so hard to push a stalled car? The obvious but incomplete answer is "inertia," that force that keeps objects at rest resting and objects in motion moving. The complete answer has to do with how objects acquire their mass. And the subject of mass, in turn, leads to the elusive subatomic particle called the Higgs boson, thought to endow particles with mass. It is named for the British physicist Peter Higgs who proposed its existence in the late 1960s. The Higgs particle so neatly dovetailed with everything physicists knew, they took up the hunt. Like detectives poring over a crime scene, they are hunting for clues in the wreckage that is created every time subatomic particles collide head-on. Two years ago, physicists believed they had the Higgs cornered, but in a critical series of experiments, it eluded the world's most powerful atom smasher. Physicists are convinced the Higgs is out there. And, they intend to find it by building an even more powerful atom smasher.

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Tesla, the German design, uses superconductors to accelerate electrons and positrons.
PHOTO BY GERMAN ELECTRON SYNCHROTRON DESY, HAMBURG, GERMANY

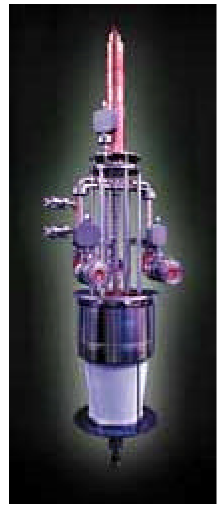
Straight And Narrow

Next Linear

Particle accelerators come in two basic designs. Linear accelerators, or linacs, shoot beams of subatomic particles down a straight track. Synchrotrons speed them around a circular track. Both machines are rated according to their beam power using a unit known as the electron volt (eV). Until it was retired from service in 2000, the world's largest accelerator was the 100 billion-eV Large Electron-Positron (LEP) collider operated by CERN, the European research consortium, near Geneva. Physicists want their next collider to have a beam power of 250 billion eV.

The idea for this new machine has been discussed within the high-energy-physics community for about a decade.

What has been known from the beginning is that the next atom smasher must be a linear collider. "You have to go to linear machines if you want to study electron-positron collisions," Cornell University physicist Gerald Dugan told a recent meeting of the American Physical Society (APS) in Albuquerque, N.M. The reason has to do with synchrotron radiation, which is produced when a charged particle, such as an electron, is propelled to velocities approaching the speed of light in a circular accelerator. For physicists seeking to produce the more powerful head-on collisions, that circular movement is literally a drag on the system.



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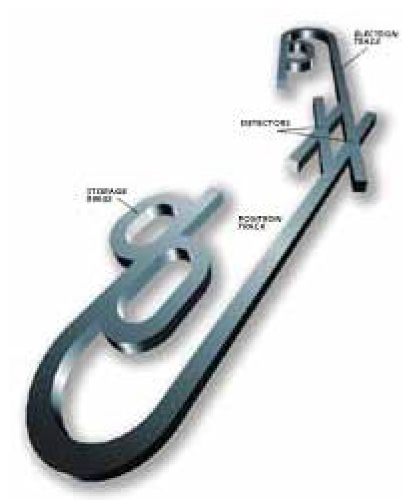
When Particles Collide

The front-running design for what is modestly called the Next Linear Collider (NLC) will follow the general layout shown above. Electrons will be created at one end of the nearly 20-mile-long machine. Positrons, the antimatter counterpart to electrons, will be produced at the opposite end. A high-frequency electromagnetic field will propel the electrons and positrons as though they were surfers who have caught the perfect wave.

Moving at a velocity as close to the speed of light as possible, the matter-antimatter conflagration taking place inside the NLC should reach energy levels sufficiently high to smoke out the sought-after Higgs.



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Inside the accelerator structure (top) microwaves created by the Klystron (center) will push electrons and positrons on a 20-mile course (bottom) to a collision inside the detectors.
ILLUSTRATIONS BY SLAC

A second approach to accelerating particles is being developed by the Deutsches Elektronen Synchrotron (DESY) in Hamburg, Germany. The German physicists' plan envisions building a 20-mile-long X-ray laser collider using superconducting cavities, illustrated on page 1. Known as Tesla, the DESY design offers several technical advantages over the more traditional design proposed by the American-based NLC team. For example, beams of electrons and positrons can be more tightly focused in the Tesla system. And it is more energy efficient. "Half the energy in [the traditional design] goes into heating copper, which makes the [Tesla] superconductor more attractive," Dugan told the APS meeting. On the minus side of the ledger, Tesla lacks a track record. The NLC builds on technology well established in decades of use at the Stanford Linear Accelerator Center (SLAC).

Watching The Crash

Physicists will record what happens when electrons and positrons collide by using a special camera, which they refer to as the detector. As with the collider, the details of the tiny detector are still being refined. Basically, it's a digital camera. It consists of charge-coupled devices (CCDs) arranged much like the sheets of a roll of paper towels. The detector surrounds the narrow tube in which the electron-positron collisions will occur. In the fraction of a second after each electron-positron collision, the CCDs will report to a computer what, if anything, they have observed. All of this information will be recorded in a massive database. Later, teams of a hundred or more physicists will comb through the database. Working with as many as 300 million pixels of information, physicists will track down each particle, like detectives following a fugitive from the trail of ATM and credit card receipts he leaves behind. "As you go to higher energies, the event rate goes down, but the events will all be interesting," predicts James Brau of the University of Oregon, who is helping coordinate the design of the detector.

Where To Build?

Currently, much of the work on the NLC is centered at the SLAC in California. Because the NLC will be a multinational effort, the nation contributing the largest portion of the atom smasher's multibillion-dollar budget will get to select where it is built. The American team has its eye on the Napa Valley. That area has enough vacant space to accommodate construction of a roughly 20-mile-long tunnel. And, it is within reasonable driving distance to the major high-energy research laboratories at Stanford University in Palo Alto, the University of California at Berkeley, and the Lawrence Livermore National Laboratory. Whether the facility is built in California, Germany or Japan, which recently began investing heavily in particle physics research, will make little difference to scientists. Once the facility is up and running--perhaps as early as 2010--most of the contact that physicists will have with the massive machine will be through the Internet.

Most physicists predict that the new collider will provide definitive proof of the existence of the Higgs boson. They expect the payoff to be enormous in terms of understanding how the universe is constructed. Even bigger surprises could be ahead if Higgs fails to show up. Some of the most fundamental theories about the structure of the universe could be in jeopardy, predicts Chris Quigg, a particle physicist for the Department of Energy's Fermilab, near Chicago. "The Higgs boson has to exist at a level below 1 trillion eV or the world gets interesting," he says.